**Science Committee of the U.S. House of Representatives**
**Field Hearing: Fueling the High Tech Workforce with Math and Science Education**
**Campbell High School, January 23, 9:00 a.m.**
**Testimony of Dr. Paul Ohme, Director, Center for Education Integrating Science, Mathematics, and Technology (CEISMC), Georgia Institute of Technology**

Honorable Representative Gingrey, members of the SCIENCE Committee of the U.S. House of Representative and other citizens present, thank you for the opportunity to appear before you to address how elementary, secondary, and postsecondary mathematics and science education is critical to innovative scientific research and to our high tech economy.

There are four major points that I would like to make and expand upon in my remarks:

First, the single, most important step that the federal government should take to improve K-12 mathematics and science education is

- **To create and support an unequivocal expectation that all children CAN and WILL learn mathematics and science at a high level.**

Second,

- **The single most important factor related to student achievement is a highly qualified, engaging, motivated teacher that is committed to the success of every student regardless of their background.**

Third,

- **Institutions of higher education, particularly mathematicians, scientists, and engineers are a key component in developing a seamless horizontal and vertical system of science, technology, engineering, and mathematics (STEM) education leading to a competent technological workforce.**

Fourth, and this may be the most harsh to consider

- **In order to have students achieve at proficient and advanced levels, they must be engaged in learning at proficient and advanced levels. Perhaps it should be considered that the reason, that more than one-third of the students tested on the National Assessment of Educational Progress (NAEP) perform at the below basic level, is because they are being taught at the below basic level. Perhaps the diminution of achievement overtime seen on the TIMSS assessment**

**by students in the United States is because the teaching and curriculum are redundant rather than taking all students continuously to the next level. We may be harvesting exactly what we have planted.**

Allow me to expand on these points. The mathematics, science and technological skills of the resident workforce present a quality of life issue for all communities. The ability to attract and sustain consequential employment opportunities is increasingly reliant on the conceptual understandings, reasoning adeptness, and technical skills found within science, mathematics and technology. In order for communities to thrive, it is imperative that students in these communities are supported in acquiring the depth of content knowledge and skills of mathematics, science, and technology sufficient for them to make personal choices and decisions that impact their communities. This *quality of life* embraces workforce competency, economic development, informed and engaged citizenry, and stewardship and delight in everyday phenomena encountered in the natural world.

Therefore, it is my premise that the single, most important step that the federal government should take to improve K-12 mathematics and science education is

- **To create and support an unequivocal expectation that all children CAN and WILL learn mathematics and science at a high level.**

By a "high level", I mean that the academic program of study that every high school graduate completes should be one of opening doors to all possibilities, rather than limiting the aspirations of any student based on the perceptions of others.

How can this high level of access to mathematics and science be achieved for every student? By providing:

- **A highly qualified teacher in every classroom**. That means a teacher with deep content knowledge, the ability to develop disciplinary understanding within each student, the confidence to assist every student in developing the skills and enthusiasm as a life-long learner, and the commitment that every child is capable and will learn meaningful mathematics and science.
- **A content rich, conceptually based curriculum** that supports every learner in developing disciplinary conceptual understanding that they can apply to familiar and unfamiliar, yet to be encountered, situations. This means that the curriculum is experientially based and allows students to apply their learning, the true evidence that learning has occurred. Therefore, the curriculum allows students to make connections to real world applications, including career knowledge in the context of the learning experience.

- **Learning resources** necessary for exploring the disciplines of mathematics and science consistent with the nature of these disciplines. This includes access to technologies, laboratory equipment, chemicals, and apparatus sufficient to explore natural phenomena as well as experiment to determine the impact and consequences of changing variables in various situations. Students should be developing skills in developing empirical evidence, analyzing and synthesizing data, and evaluating the efficacy of the information they are examining to make informed decisions. These are skills that have life-long implications for success in all fields and for participating as informed citizens in this democracy and the global world.

**Engagement of Mathematicians, Scientists, and Engineers** In order to have highly-qualified teachers, content-rich-conceptually-sound curriculum, and learning resources consistent with the nature of the disciplines, it is essential that **practicing mathematicians, scientists, and engineers** are involved in the process. These disciplinary professionals must be engaged in identifying and nurturing the future K-12 teachers of mathematics and science who will be the first teachers of the future scientists and mathematicians. These disciplinary professionals can contribute to ensure accuracy of scientific and mathematical content in the curriculum as well as fidelity to the nature of these disciplines, including scientific, analytical, thinking. It is critical that we come to consider the mathematics, science, engineering "pipeline" as including the classroom teachers themselves, as well as the mathematicians and scientists who teach them, as well as every student who is a potential scientist, mathematician, or engineer.

More than a mathematics and science pipeline, it is critical that we recognize mathematics and science education as part of a system, a cycle that must include attracting outstanding individuals to become teachers of mathematics and science, so that they can support, motivate, and advance the learning of the K-12 students they encounter, the future scientists and mathematicians. This means that current scientists and mathematicians must identify and support potential teachers of mathematics and science, just as they nurture the future scientists, mathematicians, and engineers. In other words, while we are working to attract the "best and the brightest" to become full participants in the technological workforce of the future, we must work as diligently to attract the "best and the brightest" to be teachers of mathematics and science. These teachers, disciplinary faculty, and K-12 learners are all part of the equation that has the potential to lead to workforce competency critical to innovative scientific research and to our high tech economy.

As to the question of how we can "grow, educate, attract and retain the best and brightest scientists and engineering students?" (Based on the involvement you have had with math and science education programs at the **U.S. Department of Education** and the **National Science Foundation** as well as those in the **state of Georgia**, what are the most important and effective components of these programs?)

I reiterate

- **In order to have students achieve at proficient and advanced levels, they must be engaged in learning at proficient and advanced levels.**

What are some of the factors that will contribute to every student learning at proficient and advanced levels? Beyond providing a highly qualified teacher, content-rich-conceptually-based curriculum, scientific learning resources, and substantively involving mathematicians, scientists, and engineers, the following need to be relentlessly supported:

- **Returning teaching to its place as a respected profession to be considered by the best and the brightest as a noble and rewarding career choice.**

- **Providing sufficiency of time for the generation of evidence of what works (or doesn't), in what context, for whom, and why it works.**

- **Targeting and sustaining federal dollars.**

**The Professionalization of Teaching** Research reports of the Education Trust and others shows that the single most important factor in student achievement in mathematics and science is the concept depth of the teacher. Classroom teachers of science and mathematics must have facility with not only the study of science and mathematics but also the practices of science and mathematics. Professional growth experiences for teachers cannot be limited to random workshops and disconnected courses. Rather, teachers should be supported in an extensive professional growth continuum beyond initial certification. Each individual teacher should be supported in developing a database of professional growth experiences to complement and advance their talents. As research is foundational to science and mathematics, teachers should be afforded the opportunity to participate in scientific and mathematical research that they can then translate into new learning experiences for their students. It must be recognized that it is no more appropriate for every teacher to have the same set of learning experiences, than it is to presume that every high school student needs the same set of learning experiences. However, there should be agreement on the expectation of outcomes, knowledge, and skill to be demonstrated by every teacher, just as there should be a common set of high expectations of demonstrated learning and application for each child.

The challenge of enticing some of the best and brightest into the field of mathematics and science **teaching** cannot be overlooked as part of solution to problem of advancing the workforce competency related to innovative scientific research and to our high tech economy. The disparity in the salary that an engineer with a bachelor's degree can command versus a teacher with a bachelor's degree has contributed to making teaching a less attractive career.

The problem of inviting outstanding individuals into the teaching of mathematics and science is compounded by the permeation of the societal challenges of poverty and violence into the school house. Therefore, we must be steadfast in establishing mechanisms to reaffirm teaching as a noble profession and in supporting teachers in their professional growth, with appropriate classroom resources and technologies, which promote them in taking their students to the highest level.

**Sufficiency of Time and Evidence** Involving scientists, mathematicians, and engineers in the K-12 continuum is a relatively recent scenario. Therefore, we need the federal government to financially support the pilot endeavors at a sufficient level and for a sufficient amount of time to generate evidence of what works, where, and under what circumstances. Sustained federal funding is necessary in order to gain evidence on best practices when linking active mathematicians, scientists, and engineers to the education of K-12 mathematics and science teachers and their students. The recent support of the federal government for the **National Science Foundation's (NSF) Math and Science Partnership** is an exemplar of engaging practitioners, of education and mathematics, science and engineering, to address the acceleration and advancement of mathematics and science education for all.

Hallmarks of the NSF Math and Science Partnership are partnership, evidence and shared accountability resulting in institutional change among all core partners. This is unique among federal support and essential to success. It includes the substantive partnership of university/college mathematicians, scientists, and engineers with K-12 school districts, focused on generating evidence of effective practices in advancing the demonstrable achievement of all students in mathematics and science. Attached below is a copyrighted article taken from the Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition describing some of Georgia Tech's experiences with university/K-12 partnerships.

The Comprehensive MSP, the Targeted MSP, and the Research, Evaluation, and Technical Assistance MSP awards have been supported for less than three years. The new MSP Teacher Institutes for the 21st Century are less than four months old. These programs are exceptional in that they are defining successful partnerships as being responsive to the distinctive characteristics of the local community, calling for joint planning among university and K-12 partners, clearly defining the role of each partner, benchmarking to demonstrate progress, creating mechanisms for self-correction, and requiring shared responsibility, benefit, and accountability.

It is essential that congress support the continuation of these efforts, in diverse communities, with different partners, and with varied foci in order to generate a sufficient evidential research base that can inform full implementation in school districts across the United States. As this evidence is generated in these experimentally NSF supported higher education and K-12 partnerships, the information can be used to invigorate broader implementation in school districts across the United States.

**Targeting and Sustaining Federal Dollars** It is critical that federal dollars, whether transmitted through the National Science Foundation or the U.S. Department of Education are targeted to the school districts involved, rather than tangential. Tangential efforts have been shown to have limited-short-lived impact. Targeted federal dollars should be consistent with the local master plan for advancing mathematics and science achievement. Only school districts that have committed to transforming mathematics and science education and who have defined strategic efforts to engage university mathematicians, scientists, and engineers should be provided the resources to accelerate the implementation of the already defined plan.

Overtime, students and teachers in classrooms change. Therefore, true educational transformation cannot occur classroom by classroom. Whole mathematics and science system reform, which is seamless vertically and horizontally, must be implemented. Only school reform in which the university/college community are simultaneously changing to support sustained change over time, including the recruitment, training, and retention of outstanding individuals as teachers of mathematics and science, as well as the scientists, mathematicians, and engineers of tomorrow, will result in the quantum leap that is required to advance the technological economy of the U.S. in the 21st century. Only through the sustaining of targeted federal dollars over a period of five to ten years will we be able to garner the evidence to demonstrate the efficacy of such accountable-action-oriented partnerships.

Universal Implementation The U.S. Department of Education is poised to play a pivotal role in supporting school districts in partnership with higher education in translating the lessons learned, the evidential-base garnered through MSP research efforts of NSF, into common practice in all classrooms across the country. While the flow of dollars for support of the U.S. Department of Education Math and Science Partnership are just starting to be distributed, it is important that local partnership, involvement of mathematicians and scientists, and accountability be maintained as individual states make decisions as to which best practices they will promote.

Related to how K-12-higher education partnerships can reduce the need for remediation, promote interest in mathematics and science education, and reduce the number of dropouts, especially for underrepresented populations, we may need a paradigm shift within the following:

- **Assessment, Accountability, and Motivation**
- **Acceleration versus Remediation**

**Assessment, Accountability, and Motivation** As we are concerned with elementary, secondary and postsecondary math and science education in its criticality to innovative scientific research and to our high tech economy, we must be concerned with assessing the results we want, rather than those that are most easily measured, but provide little meaning. Assessing the memorization of facts in science and basic computation in mathematics are not sufficient to preparing the scientific, mathematical or teaching workforce of the future. The mathematics and science content knowledge of today is much vaster than when we were in school and continues to escalate at an incredible rate. If you look at just a few of the top ten list of scientific discovers in 2002, as reported by *Science Magazine*, you will discover heretofore unheard of roles for various RNA-s, including micro-RNA-s, elementary-particle physics involving solar neutrinos (a mystery for the past thirty years), and progress in the field of genome studies that will make it possible to defeat malaria and hunger. Nanotechnology, chaos theory, and fractals were unknown just a few decades ago. As the content of mathematics and science is enormous and ever expanding, we can no longer look to mere measures of factoids. Rather we must assess the conceptual understandings, which are the underpinnings of science and mathematics. We must assess the critical ways of thinking, analyzing, synthesizing, evaluating and generating new knowledge that are the signature of the scientific and mathematical disciplines. We must find ways of assessing the applications of these concepts in new situations. Only by developing assessments that allow teachers and professors to determine what students appear to understand, as well as to diagnose misconceptions so that they can be addressed, will we successfully develop the next generation of scientific leaders, teachers, and citizens.

The federal government must support the development of appropriate measures for assessing the advancement of achieve in mathematics and science. In holding partnerships, schools, communities and universities accountable for improving scientific and mathematical learning, attention must be paid to motivational processes rather than solely punitive disincentives.

**Acceleration versus Remediation** Rather than focusing on remediation, Georgia Tech has chosen to focus on acceleration. That is to say, that the pre-college and college support programs are designed to immerse all involved, whether pre-college students, their teachers, or undergraduate and graduate students in the exciting content that is science, mathematics and engineering. By engaging learners at every level in meaningful content and continuously successful experiences in learning, we are increasingly attracting more and more people to the opportunities resident in careers in scientific academia, industry, and teaching. It is trite to say, but success breeds success. By engaging students in successful, yet challenging, scientific experiences, learners come to recognize their innate potential.

**CEISMC Endeavors** Most engineering-scientific Research-1 institutions, particularly those without a College of Education, focus on generation of new knowledge and the training of the next generation of scientists, mathematicians, and engineers. However, since the early 1990's, the Georgia Institute of Technology (Georgia Tech) has supported CEISMC (the Center for Education Integrating Science, Mathematics, and Computing) in improving the beginning of the intellectual pipeline, the K-12 students, in mathematics and science. Through CEISMC, Georgia Tech, links together the intellectual and research expertise of scientists, mathematicians, and engineers, their graduate students, and undergraduates with the K-12 teaching practitioners and their students. Through CEISMC's Teaching and Learning Camps, teachers' scientific and mathematical content and pedagogical skills are advanced with applied curriculum developed in concert with researchers. Middle grades students participate in these summer camps thus extending their curriculum beyond their regular school classroom and inspiring them to return to school with renewed enthusiasm for their ability to learn science and mathematics.

Professional Development Another professional development opportunity sponsored by CEISMC is the Georgia Industrial Fellowships for Teachers (GIFT) program. This is a partnership with the scientific, mathematical, and technological corporate sector, university researchers, and schools, which places veteran teachers in scientific and corporate research experiences for six to eight weeks each summer. Since GIFT's inception more than 750 placements have been made, with an average of 75 placements each year. These teachers are supported by mentors to translate their research experiences into classroom learning activities for their students once they return to their classrooms. In both settings, teachers take ownership of their professional growth and positively comment on how they have been reenergized in their teaching of mathematics and science and feel renewed as a professional.

Linking Practitioners and Learners Georgia Tech's Student and Teacher Enhancement Partnership (STEP), an NSF sponsored GK-12 program partners Georgia Tech graduate and undergraduate students with teams of teachers at six majority-minority metro-Atlanta high schools per year with three primary goals: To use the unique talents and energy of the Georgia Tech students to help address the pressing needs at the schools; to promote long-term, mutually beneficial, and multi-faceted partnerships at these school; and to provide the Georgia Tech students with a teaching internship experience that would benefit their professional growth and subsequent career, whether in academia, industry, or education. In its third year, fifty-six graduate applicants applied for thirteen slots, with 54% filled by African American students.

Evaluation of this program show that all participants, teachers, their students, graduate students and undergraduates (paired with graduate students) have benefited from this program. Among the outcomes for graduate students are academic content mastery, academic efficiency, professional skills, presentations and publications, interest in teaching and advanced pedagogical skill. Schools benefit from student instruction in cutting-edge science and mathematics, instructional materials development, student mentoring, access to educational technologies, support for student research, professional development for teachers, and connections to the Georgia Tech campus. Providing access and linkages to undergraduates, graduates, and faculty researchers gives students, many of whom will be first generation college students an understanding of the power and possibility, which exists within them if they apply themselves. These students can visualize themselves in these successful experiences for the first time, because they are given access and support.

In addition, this work is generating a new body of knowledge related to Partnerships which bridge the cultures of K-12 and universities in which scientists, mathematicians, and engineers are substantively engaged. Three stages of partnership encompassing six factors of embeddedness, strategic needs, formation, operation, process outcomes, and performance outcomes are described. (See Partnering Across Cultures: Bridging the Divide between Universities and Minority High Schools, M. Usselman, D. Llewellyn, D O'Neil, and G. Kingsley).

*Pre-college Mentoring* But success can only occur when each student is fully supported with outstanding teachers, a meaningful conceptually based curriculum, and scientific learning materials, as well as a community of individuals letting each student know they can be successful. The latter can be accomplished through a number of mentoring approaches. CEISMC partners with corporate mentors, such as **BELL**SOUTH employees, in working with teachers and middle grades students early enough in their education to support them in embracing success in science and mathematics. CEISMC's Mentoring Program (CMP) links undergraduates as mentors with middle and high school students.

*Pre-College Advanced Curriculum* While providing mentoring experiences for students engaged in Advanced Placement Calculus and Computer Sciences, CEISMC is also partnering with three metro-Atlanta school districts in the expansion of their advanced learning programs. While each of the CEISMC collaborative efforts has linked university disciplinary faculty and loaned CEISMC specialists to the school districts to develop programs to increase participation and success, particularly among minority students, to honors and advanced coursework, each of these endeavors is unique to the school districts (Cobb, DeKalb, and Atlanta Public Schools), and therefore reinforces a core premise of all CEISMC's work, that is it must be responsive to the needs of the school districts. A cookie-cutter approach does not work, in mentoring, professional development, or in curricular programs.

*Pre-College Technology* In keeping with the notion of acceleration rather than remediation, CEISMC is developing websites that focus on engaging students and their families in the power, fascination, and career opportunities resident in science, mathematics, and engineering. CEISMC also develops websites for collaboration among teachers, mentors, participants, and faculty in order to increase the opportunity for continued interaction and "just-in-time-learning." The latter refers to when a learner is working along and encounters something that is particularly challenging, they can share that challenge and work collaboratively to surmount and own the necessary understanding.

*Continuous Support—Once at Georgia Tech* While the primary focus of CEISMC-Georgia Tech's efforts are at the pre-college level, while impacting the collegiate level, Georgia Tech has a number of successful programs which have proven to support accomplishment, particularly among minority students. OMED (Office of Minority Education) serves Georgia Tech underrepresented students—African American, Hispanic, and Native American—through a strategy of academic success and persistence through "prevention." OMED's research has found a strong correlation between the minority students first term GPA and their graduation rate five years later. Consequently, Georgia Tech's goal is to work toward a minority graduation rate of 85% with a cumulative GPA of 3.0 as the standard for academic performance. OMED fosters this through its "academic pre-season" embodied in programmatic pieces for entering students. Georgia Tech supports students in academic transition programs that provide continuous analysis and assessment with real-time feedback as students are supported in their academic immersion experiences. OMED's activities have shown an increased closing of the gap among Black students retention benchmarked against the total Georgia Tech population, and shows that Hispanics are retained at a higher rate than either Blacks or the Georgia Tech population.
More detailed information relating to OMED is attached.

*FOCUS* Georgia Tech is also focused on the success of underrepresented populations at the graduate level. *FOCUS* is a graduate student recruitment program rooted in marketing: marketing Tech, marketing Atlanta, and marketing graduate school. The experience opens these students, many of whom are first-generation college graduates, of the potential research and educational opportunities waiting for them. Many underrepresented college graduates are focused first on entering the world of employment, without having the opportunity to consider the benefits of graduate study. FOCUS is a collaboration of Georgia Tech and the King Center. It invites minority graduates to a four day experience in Atlanta. It not only exposes students to the faculty and facilities of this Research-1 Institute, but also to the history of the city as the seat of the civil rights movement. It is no small wonder that *FOCUS* is timed to coincide with the city's celebration honoring Martin Luther King, Jr.

These efforts are demonstrating success. Tech currently holds the distinction of being first in the number of master's degrees and doctoral degrees conferred upon African-Americans. It is notable that one-third of the graduate-level students enrolled at Georgia Tech participate in *FOCUS.*

**Summation** Ultimately, it is vital that all students be supported in access to, preparation for, and participation in courses that will allow them to make individual decisions as to their post-secondary pursuits. Whether those decisions are made while in high school, or a decade later, students should not be limited in their options for work, military, technical college, or university pursuits by the judgment of others as to what coursework they are capable of, or may need. The single most important factor related to student achievement is a highly qualified, engaging, motivated teacher that is committed to the success of every student regardless of their background. But additional supports, through meaningful curriculum, learning resources, mentoring, and bridging/transitioning support programs have demonstrable impacts on student success. This is true for students underrepresented in the fields of mathematics, science and engineering as well as those well represented. Finally, the nature of partnership among universities and K-12 schools is critical and must embrace mutual respect, shared benefits, and responsiveness to the needs of all involved.

The nation and Georgia have experienced an increasing reliance on the scientific and technical skills of those beyond these shores. We must rededicate ourselves to the support of the human capital resident in our youth, the leaders of tomorrow, the economic engine of our future.

# Partnering Across Cultures: Bridging the Divide between Universities and Minority High Schools

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**Abstract**
The historical mission of most engineering-dominated Research-1 universities is to create new knowledge and to train students in technological fields. In the absence of a College of Education, and given an institutional culture prioritizing scholarly research, institutions such as Georgia Tech often do not have a long history of systemic faculty involvement in the K-12 educational community. However the current national focus, initiated by public funding agencies such as the National Science Foundation, encourages academic scientists and engineers to shoulder some of the responsibilities for the quality of science, technology, engineering and mathematics (STEM) education at the K-12 level, and to do this by developing university-K-12 "partnerships." Unfortunately, given the vast cultural differences that exist between universities and K-12 schools, these partnerships too often flounder, never managing to bridge the divide to the point of mutual trust, mutual respect, and mutual benefit.

We are currently in the third year of an NSF-funded GK-12 project, the Student and Teacher Enhancement Partnership (STEP)[1], and are preparing to embark on a five-year extension. A major part of this project has been the building, nurturing, and grooming of partnerships between Georgia Tech and local minority high schools. As part of this project we have developed a model of partnerships that is grounded in the public policy literature and that describes the evolution of the partnerships created between Georgia Tech and four minority-dominated high schools as part of STEP. In this paper we will describe the theoretical framework of the partnership model, outline ways to assess partnership outcomes, and apply this model to the STEP program case study.

**Theoretical Framework of a Partnership Model**
As part of a separate NSF-sponsored research project, we are examining how partnerships influence STEM educational outcomes in NSF's Systemic Initiatives Program and Math and Science Partnerships Program.[2] We do so by exploring how the

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[1] NSF Award Number 0086420
[2] NSF Award Number 0231904. We are in our second year of this three-year project. For more details on this research, "Alternative Approaches to Evaluating STEM Education Partnerships: A Review of

emergence, operation, and in some cases, dissolution of partnerships influence the process by which STEM educational outcomes are pursued and achieved. For the purposes of this research, we define *partnerships* as voluntary arrangements between organizations, anchored by agreements, to promote the exchange, sharing, or co-development of products or programs designed to stimulate STEM education.[3] Partnerships are a particular form of interorganizational collaboration. However, they are distinctive in that participants are not merely bound by mutual interests. They have also developed agreed goals and responsibilities for achieving these goals[i]. Such agreements are usually articulated in formal contracts, memoranda of understanding, or statements of work. However, we do not exclude the informal "hand-shake" variety of agreement in our definition. We also note that the term *organization* is applied loosely to include the organized interests of parents and other interest groups.

In the multi-disciplinary field of public policy research, partnerships have been studied from multiple perspectives including organizational theory and interorganizational relations. Interorganizational studies are the umbrella from which studies of organizational networks, partnerships and alliances have emerged[ii]. In other policy contexts interorganizational conceptual foundations have been used to study the relationships among firms, not-for-profits, public agencies, and in public-private partnerships. Researchers from myriad disciplines have contributed to the conceptual foundations of interorganizational studies including scholars from business, sociology, economics, public administration, and anthropology. These studies have been pursued using a wide-variety of research methods including cluster analysis, graph and network analysis, qualitative case studies and social mapping techniques, and various statistical regression techniques. Consequently, interorganizational concepts cover a wide range of partnering behavior and provide an analytic language that is sufficiently developed and useful to span the multi-disciplinary world of STEM education.

While many STEM education programs may seek to link partnership efforts to positive outcome variables such as increased student achievement, researchers and evaluators from several fields have noted that studies of interoganizational relations (such as partnerships) rarely address outcomes[iii,iv,v]. It is far more common for partnership studies to try and explain the reasons for the formation and structure of relationship rather than subsequent actions and value-added to the individual partners[vi]. Alternatively, studies will posit that partnership is a positive factor and then provide evidence to support the premise.

Another issue is that partnerships are often treated as rational, strategic acts which organizations form to control or influence their working environment. From this perspective organizations enter into the partnership as a means of gaining information, control over their strategic environment, or to secure vital resource flows[vii]. However, this

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Evaluation Methods and Application of an Interorganizational Model," please visit the project website at http://www.prism.gatech.edu/~gk18/STEM

[3] This definition draws from Gulati and Gargiulo's (1999) definition of alliances among firms. Their work provides a general summary of how alliances emerge and develop products, technologies and services.

is an under-socialized, overly rational point of view that does not account for existing relationships in which an organization is embedded[viii]. Partnerships also emerge because organizations have a long-standing working relationship and one is persuaded by another to participate. Organizational institutionalists argue that rationales for participation in a partnership may be strategic, but they may also be coercive, mimetic, or persuasive as well.

There is also a difficulty in interorganizational studies in articulating when a failure has occurred. Studies have found a high incidence of failure amongst partnerships and joint ventures[ix]. However, there has been a good deal of uncertainty regarding when a partnership has failed. For example, studies have concluded that failure is represented by the end of the partnership. If the individual parties to the partnership have achieved their goals and agreed to dissolution then it does not seem appropriate to label such an experience a failure. Even if only a few of the participants to a partnership benefit while others do not, then the result can be ambiguous. In the case of STEM educational outcomes the ultimate determination of success for many political and educational leaders is improvement in the performance of students in their abilities and on test scores. Even partnerships that have dissolved may have served their purpose in creating a climate to engender and sustain these improvements.

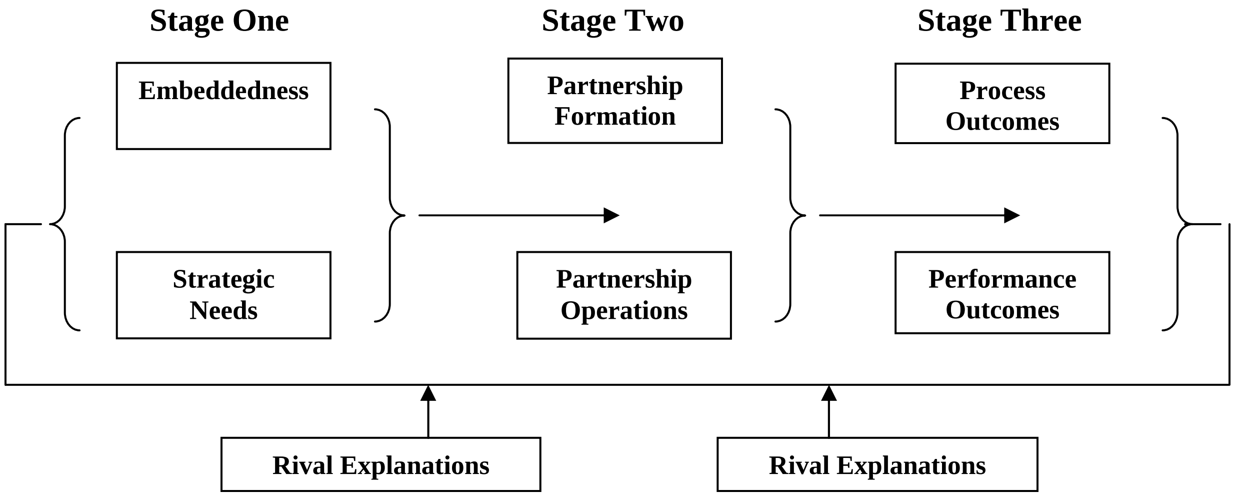
A final issue in evaluating partnerships is the transportability of successful partnerships from one setting to another. A form of partnership that is found to be effective in a rural setting may not apply well in an urban area. Affluence, community culture, or ethnic diversity may act as additional contingencies affecting the link between partnership and educational outcomes. Essex (2001) offers seven characteristics of effective partnerships between a K-12 school and a university but cautions against of one-size-fits-all application[x]. Sirotnik and Goodlad (1988) also warn against becoming too focused on a single model of effective collaboration[xi].

To develop a useful tool for evaluating STEM partnerships, models must be robust enough to address these challenges. This means that the model should attempt to establish clear relationships between the partnership and the desired outcomes. There must also be a clear focal relationship (e.g., a particular dyadic partnership, or a network of organizations, or an individual organization). Success and failure need to be judged in terms of the overall objectives of partnership rather than measuring failure through the participation of individual members. And studies must build towards robustness by being comparative not only between highly embedded and non-embedded organizations, but also among partnerships in different types of communities (e.g., advantaged vs. disadvantaged; homogenous vs. heterogeneous; large vs. small school system; or rural vs. urban geographic location).

Partnership Conceptual Model

Through this research, we are developing a conceptual model for linking partnerships and outcomes. Six concepts are drawn from organizational and interorganizational relations studies into a conceptual model that links the pre-conditions for partnership, with partnering activities, and finally partnership outcomes.

## Partnership Conceptual Model




**Stage One**

This model captures the pre-existing conditions in terms of strategic needs and the embeddedness in relations among organizations prior to the partnership.

- *Embeddedness* describes the number and types of relationships that organizations have with one another prior to the development of a partnership.
- *Strategic needs* describes the types of resource and legitimacy needs confronting individual organizations prior to a partnership and whether there is a congruence or complimentarity in these needs.

The concepts of embeddedness and strategic needs are not mutually exclusive and are likely to work in concert. In Table 1, we offer a two by two matrix describing some of the possible combinations. Each partnership or set of partnerships within a STEM project can be classified according to this chart.

**Table 1: Positive Embeddedness and Congruent Strategic Needs**

| | | Congruence of Strategic Needs of Partners | |
|---|---|---|---|
| | | **Low** | **High** |
| **Level of embeddedness** | **Low** | I | II |
| | **High** | III | IV |

Embeddedness may occur in either a positive or negative form. Two organizations may know each other well, have lots of experience working together, yet really dislike and distrust the other. Thus, each partnership will have to be classified as high (negative) or high (positive) in terms of embeddedness. In Table 1, low levels of embeddedness may signify that the two organizations have little history of working together. Similarly, all organizations have strategic needs. The issue in this model is whether those needs are 1) strategically related to the objectives of the partnership, and 2) congruent or complementary.

Just because partnerships fall outside of quadrant IV does not predict that they will be a failure in term of process and performance outcomes. But it does indicate that the nature of partnership needs to be adapted to reflect these conditions. For example, partnerships in quadrant II exhibit high levels of congruence among partners in their ability to satisfy strategic needs through the project. But these organizations are low on embedding meaning that they do not have a history of working together. We would anticipate that the partnership process variables of stage two will exhibit higher transaction costs and formalization of agreements if this partnership is to be successful. Similarly, partnerships in quadrant III have high levels of embeddedness but low congruence of strategic interests. In order to achieve successful outcomes the partnership must devise ways of building on the pre-existing trust among organizations with incentives that motivate the partners to fulfill their duties to the partnership. Finally in quadrant I partners do not have embedded relationships nor is there much in the way of congruent interests. Such partnerships are likely to be marriages of convenience bound by the desire to secure grant monies or other resources.

**Stage Two**

The third and fourth concepts describe the types of partnering activities that develop. These concepts are designed to describe the process of partnering and include the following:

- ***Partnership formation*** describes the types of agreements regarding the goals, resource allocations, and responsibilities of each party to the partnership. This concept captures the collective intent of the partnership and includes the following ideas:

    - *Partnership Goal* – Partnerships take aim by setting objectives that engage the full complexity of the problem or may focus on a narrower slice of the issue. The wider the focus the more likely the partnership is to require the intervention, reinforcement, and support of resources outside the school system. For example, it is not uncommon in math-science education (or in other subjects as well) for students to have a view of their life and development that does not include the application of these basic educational tools. Challenging this perception requires not only the personal interventions of the schools but also may require challenging a community culture that lacks of vision of the possibilities associated with these tools. Effectively addressing a student's need for math-science education may require enlisting role models and resources beyond those the school can provide.

- *Partnership Agreement* – Refers to the number and types of formal agreements that are entered into among the partners as a means of achieving process and performance outcomes. In general, researchers have found that embedded relationships require less formalization over time[xii]. Thus, we might predict that partnerships with positive patterns of embeddedness would require fewer agreements in order to reach positive outcomes. Attempts to formalize such arrangements may actually work to hinder such good results.

- *Partnership Focus* – Organizations are not monoliths. Instead they are comprised of groups of professions, coalitions, and operating divisions. Partnerships vary in terms of the types of different groups that have some form of interaction with one another. For example, organizations may be highly embedded but not in the relationships that are critical for the objectives of the project. For example, school system administrators may have excellent working relationships with universities. But their teachers may have no experience in interacting with university representatives. This means that for the purposes of improving teacher performance the high levels of pre-existing embedding may not produce the normal types of benefits associated with these relationships. One way of capturing this is to identify the number and types of different groups engaged in each partnership.

- *Partnership Complexity* – refers to the number of different organizations and activities within the partnership. Complexity has been posited to have four dimensions: vertical, horizontal, sectoral and spatial. Vertical refers to whether the partnership is organized into a hierarchy with clear lead organizations and clear followers. Horizontal complexity refers to the number of peer organizations operating at the same level and on similar tasks. Sector-based complexity refers to the number of organizations drawn from the public, private, and not-for-profit sectors participating in the partnership. Spatial complexity is the number of different geographic locations involved in the partnership. Highly complex partnerships are more difficult to operate and keep focused on partnership objectives, but there are also more opportunities for spillover benefits due to additional extra-partnership collaboration.

- ***Partnership operations*** describe the actual behaviors in which the partners engaged as they pursue the goals and duties of the partnership. This concept includes the following:

    - *Partnership Interdependence* -- refers to the extent that partners depend upon each other for resources or materials to accomplish the partnership objectives. Three types of interdependence have been identified: pooled, sequential and reciprocal. Pooled refers to relationships that are not highly interdependent where each partner works fairly independently. Sequential refers to relationships where the work of one partner feeds into the work of another partner and this second partner is not able to proceed until the work of the first partner is accomplished. Under reciprocal interdependence each partner must share work back and forth until it is completed. Reciprocal relationships are the most interdependent form of partnership.

- *Transaction Costs* -- these are the costs that organizations absorb in the implementation of a task. In partnerships transaction costs are almost always high because the participating organizations have to adapt to each other's method of doing business. Transaction costs can be higher if individuals from different professions are interacting (usually requiring that each learn a bit of each other's language) or if different sectors are involved (as individuals from the private and public sectors adapt to the particular rules that govern their home organizations).

- *Partnership Communication* – this refers to the frequency with which partners interact and the direction of these interactions. One of the more common complaints in university-school partnerships is that the communication flows are largely one-way with universities providing information and resources to schools. These patterns may be highly embedded and even be high in congruent interests if they contribute to the professional development of school systems and/or teachers. However, when confronted with a challenge as difficult as reforming STEM education outcomes, greater dialogue may be required in order to achieve positive outcomes.

**Stage Three**

The final two concepts describe the types of outcomes that develop from the partnership. These concepts are designed to capture the results of the partnership.

- *Process outcomes* describe the qualitative and quantitative assessments that measure whether the partnership actually achieved the goals and duties of operation. For example, under *process outcomes* we may observe whether partners were able to implement a common curriculum across schools, marshal resources among partners, bring together the support and talents of universities, parents, businesses and not-for-profits, or achieve congruence among policies.

- *Performance outcomes* assess such improvements as in the working environments of teachers, enhancements in their ability to engage in STEM education, and assessments of the performance of students on STEM topics.

Stage One and Two variables in the partnership model describe how pre-existing conditions and strategies of partnering need to be matched in order to produce positive outcomes. This is particularly true with *process outcomes*. Under Stage Two partnership variables we observe the types of interactions, agreements, resources, foci, transaction costs, etc. that are associated with a project. Stage Three outcome variables capture the degree to which these efforts are translated into conditions for successful STEM partnerships.

**The Student and Teacher Enhancement Partnership (STEP) Program—Case study**

The Student and Teacher Enhancement Partnership **(**STEP) program, funded for three years by the National Science Foundation as part of the GK-12 program, with a continuation for another five years (as STEP Up![4]), partners Georgia Tech graduate and undergraduate students with teams of teachers at six metro-Atlanta high schools per year. The discussion that follows applies the conceptual model of partnerships to the STEP program, analyzing the program based on the theoretical concepts described. A total of ten high schools, widely distributed geographically throughout the Atlanta metropolitan area and in terms of socio-economic status, have participated in the STEP program over the past two and one-half years. We will limit the current discussion to the partnership with four primarily African American schools in Fulton and DeKalb Counties.

In this report we examine the body of data collected during the STEP evaluations and organize this information using our partnership model. In doing so, we attempt to observe both the variance in partnering-related activities and the evolution of the partnership over time.

**Partnership Assessment Strategy for STEP**

The findings for this study are drawn from the on-going evaluation of the STEP program. Because the STEP program is in the early stages of development the assessment strategy is currently formative in nature, emphasizing qualitative data collection methods and descriptive analysis of the partnerships. The key evaluation issue is whether the STEP program enhances math and science partnerships (in this case between Georgia Tech, the school districts and the high schools) by introducing Fellows as a resource for teachers. Thus, in addition to the variables described above, several key relationships served as the focus for the larger evaluation:

1) Evidence of enhanced math and science partnerships between Georgia Tech, the school districts, and the high schools.
2) Evidence of effective working relationships between high school teachers and the STEP Fellows.
3) Evidence of benefits to teachers, Fellows, and high school students from participating in the STEP program.
4) Identification of factors that facilitate or hinder the achievement of the impacts identified in previous three points.

The principle evaluation method employed during the first few years is to develop case studies of each of the high schools participating in the STEP program. The narrative in each case describes the implementation of STEP from the perspective of each of the partners. In addition to the case studies, the data is examined according to the roles that individuals play within STEP. Thus, aggregate narratives are developed for Fellows,

[4] NSF Award Number 0338261

Teachers, Coordinators, and Advisers. A variety of data sources are used in this study including:

- Semi-structured interviews with Fellows, teachers, advisers, coordinators, and STEP administrators.
- Surveys of Fellows following the summer training programs for STEP.
- Document reviews of the action plans for each high school.
- Document reviews of lesson plans and assessment tools developed by the STEP Fellows.
- In-class observations of the STEP Fellows.
- Review of journals maintained by the STEP Fellows of their experiences within the high schools.

Input from high school students was also compiled through presentations and information from the STEP Fellows, such as videotapes and student evaluations conducted by individual teachers or STEP Fellows.

**Stage One: Embeddedness**

The STEP program has provided a way to partner Georgia Tech with four primarily African American high schools in which it historically has had few ties. It is worth mentioning that many of the local African American-majority schools view the local majority-white universities with a large amount of distrust, a point of view rooted in segregation and in the fact that minority schools in the southern United States have traditionally been forced to operate with far fewer resources than their white counterparts. In addition, universities often initiate "reforms" in local schools that are short-lived, leading to a healthy skepticism by veteran teachers about the university's long-term commitment. University academic faculty often approach projects presuming that they know better than the school personnel how to solve the problems of K-12 education, causing teachers to be suspicious that university involvement will just create additional work for them. The distrust is also fueled by the legacy of segregated southern universities (including Georgia Tech), by the current debate about affirmative action and the fairness of standardized exams such as the SAT, and by the lack of cross-cultural dialog between African American and Caucasian students who have never sat next to, nor competed academically with, students from the other race. So in many ways, the pre-existing relationships between the individual majority-black schools and the majority white universities are fraught with historical baggage, are examples of communities with vastly differing cultures and expectations, and therefore exhibit very low levels of embeddedness. However the central administration of these large, urban, school systems are often experienced at partnering with local universities, which provides an effective initial point of entry.

**Stage One: Strategic Needs**

For the High Schools--The four schools participating in this partnership all post low standardized test scores, and on most measures of academic achievement (including the percent of students requiring academic remediation in college) they perform well below their majority-white suburban peer schools. The demographics and 2001-2002 academic performances of the partner schools are listed in the table below.

| High School | School System | # students | % Under-rep. Minorities | % Reduced lunch | Ave. SAT | % passing AP test |
|---|---|---|---|---|---|---|
| Cedar Grove | DeKalb | 1585 | 100% | 47% | 884 | 7% |
| Stone Mountain | DeKalb | 1400 | 92% | 54% | 888 | 6% |
| Tri-Cities | Fulton | 1893 | 94% | 42% | 868 | 22% |
| Westlake | Fulton | 1266 | 99% | 33% | 898 | 22% |

The need for increased academic achievement is therefore easily demonstrable. However precisely which strategic needs are addressed by the STEP partnership? They are the needs endemic in low performing schools where the teachers are under great stress to improve academic performance at the same time as they are coping with student disengagement, transient student populations, and lack of parent involvement or support. In other words, they are:

- The need for extra adults to assist with developing and implementing laboratory exercises.
- The need for assistance with locating and coordinating educational excursions, and for planning after school clubs and organizations.
- The need for assistance in taking advantage of educational and funding opportunities.
- The need for role models and mentors for students.
- The need for expert content resource people to aid both teachers and students.
- The need for support for the use of educational technology.

On the other side, what are the strategic needs of Georgia Tech that are satisfied by STEP, and are these needs congruent and/or complementary to the needs of the schools system? Georgia Tech's needs are:

- The need for opportunities for graduate students to gain leadership, communication, and teaching skills.
- The need for graduate students and faculty members to have approved avenues for engaging with and giving back to the community. This is particularly true for our African American graduate students.
- The need for faculty to engage in educational outreach and workforce development activities to help them attract external research grants.

The needs of the two partners are therefore largely congruent since the university partners satisfy their needs through interacting with the school system partners.

**Stage Two: Partnership Formation**

Partnership Goals

- To use the unique talents and energy of the Georgia Tech students to help address the pressing needs at the schools;
- To promote long-term, mutually beneficial, and multi-faceted partnerships at these schools; and
- To provide the Georgia Tech students with a teaching internship experience that will benefit their professional growth and subsequent career, whether in academia, industry, or education.

Partnership Agreements

The Science Coordinator or Deputy Superintendent for Curriculum from each participating school system selected schools to participate in the STEP Program. The schools selected were ones that had demonstrated need, but that also had well-functioning leadership and the capacity to partner. Because of the disproportionately high participation rate by Georgia Tech African American graduate students and the high level of need in the predominantly black Atlanta-area schools, we decided after Year 2 to concentrate most of our efforts on the issues of the primarily black schools.

Partnership Focus

Two Graduate Fellows and a teacher coordinator form the initial central core of the STEP team at each school. As the partnership progresses at a school and the capacity of the school to effectively expand the partnership increases, undergraduate students are added to the mix, or new ventures, such as a pilot using a social science graduate student, are added. This increased school capacity usually takes the form of an increase in the number of teachers who claim ownership of the school-Georgia Tech partnership and who understand the value of, and the optimal ways of interacting with, the graduate Fellows. In each school the partnership has evolved differently. The STEP staff provides guidance and consultation, but the central philosophy of STEP is that the nature of the partnership is defined by the people directly involved. The STEP co-PIs choose the graduate Fellows, give them training, and put them into the field to work in ways that best fit their talents and inclinations and that most effectively address school needs.

Partnership Complexity

*Vertical Complexity*—Georgia Tech is the lead STEP organization, maintaining partnerships with multiple high schools. However substantial effort has been invested in moving the relationship away from a leader and follower status, and encouraging the high schools and teachers to take the lead on initiating projects. However the central STEP administration effectively holds the project together.

*Horizontal Complexity*—STEP involves multiple high schools, and multiple Georgia Tech academic units, centers, and laboratories. In this regard, the project is highly complex, and relies on creating multiple horizontal connections between independent entities. However since only one university is involved, this decreases the problems of multiple collaborations between peer institutions.

*Sectoral Complexity*—STEP is primarily a partnership between the university and the schools. However long-term sustainability probably requires that additional partners be added from the private sector. STEP has initiated a campaign to attract private sponsors, which will undoubtedly add to the complexity of the general partnership.
*Geographic Complexity*—STEP operates only in metro-Atlanta, within commuting distance for the graduate Fellows. This simplifies many aspects of the partnership.

## Stage Two: Partnership Operation

Partnership Interdependence
The STEP PI and co-PI do not dictate what the team is to do, but instead serve to "run interference" and ensure that the program runs smoothly, that the activities are consistent with the goals of the program, and that all of the team members are communicating effectively. The partnerships with each school are reciprocal, requiring that each side initiate actions, and follow through with support for the other side.

Transaction Costs
The most substantial cost of STEP is in the graduate Fellow stipends, tuition, and other associated cost-of-education expenses. Money is also invested in the form of staff salaries. Therefore in this partnership, components with "high transaction costs" are usually defined as those that take lots of time and energy from the STEP staff and from the graduate Fellows.

At the school level, each STEP team is led by a Teacher Coordinator who is paid a $2,500 stipend. That teacher is responsible for recruiting colleagues into the program, and for overseeing the placement and activities of the STEP Fellows. Each Teacher Coordinator is provided with $2,000 for materials and supplies, and $1,000 to support teacher professional development activities. Additional teachers who become involved with the program are provided with financial compensation, up to a total of $2,000 per school. In addition, each STEP Fellow is provided with money for supplies--$500 per graduate student, and $250 per undergraduate student

Partnership Communication
Many of the most serious problems that have arisen during STEP can be traced to a breakdown in communication that leads to different expectations between participants, such as between a Fellow and a teacher. We have learned that prompt and regular communication, regular monitoring of graduate Fellow activities, and a willingness to quickly change course when people are dissatisfied serves to minimize the problems that stem from poor communication. One problem of partnering with minority schools is that the school personnel often are not comfortable using e-mail, which is the primary mode of communication at the university. This state appears to be changing, however, making the communication routes much easier.

## Stage Three: Process Outcomes

As indicated in the Partnership Assessment Strategy section above, STEP outcomes at this stage are primarily: 1) evidence of enhanced partnerships, 2) evidence of effective working relationships, and 3) evidence of benefits to teachers, Fellows, and high school students. These outcomes are described under Performance Outcomes. Process Outcomes include the actual operation of the partnership, and the infrastructure developed to support the program. These are detailed below.

<u>STEP Summer Training Course</u>
Before they are placed in the classroom, STEP Fellows receive ten weeks of training during the summer at the start of their fellowship period. The goals of this training are threefold: to start the work of building partnership teams and planning for the academic year; to give the Fellows a "toolbox" of knowledge and resources to use once they arrived at the high schools; and to provide ample opportunity to explore relevant topics in education and to practice using the tools that they are learning. The expectation is that at the end of the ten weeks the Fellows will be ready to be fully participating members of the teams at the schools, ready to act as content expert resources and to engage with the teachers as partners in the educational mission of the high school classroom.

<u>School-Based Partnering Activities</u>
The action plan, developed by each school team, details the types of activities that best fit the needs of the school and the talents and professional and personal desires of the Fellows. Examples of the activities include:

- *Student Instruction*-- Fellows can assist partner teachers with instruction in the classroom in the form of hands-on laboratory experiments, group research projects, active group discussions of science topics, and/or short lectures on content.
- *Instructional Materials Development*—Fellows can develop instructional materials, or adapt existing materials to reflect more inquiry learning. The learning objectives covered depend completely upon the needs of the specific classroom.
- *Student Enrichment and Mentoring*-- Fellows are often involved in direct tutoring and mentoring of students, and in coordinating activities such as high school chapters of the National Society of Black Engineers (NSBE Jr.) and Science Olympiad.
- *Educational Technologies*—Fellows can provide teachers and students with assistance in implementing educational technologies in classroom projects and curricula, including initiating web-based classroom resource and discussion pages.
- *Student Research and Science Fair Projects*--Fellows provide invaluable assistance to students in conceptualizing a viable science experiment, providing feedback on the appropriate uses of the scientific method, assisting with locating appropriate research equipment and supplies, reviewing experimental progress and data, and advising on presentation of results.
- *Teacher Professional Development*—Fellows have designed and implemented staff development activities for teachers, often focusing on the use of educational technology.
- *Georgia Tech Connections*—Fellows are very effective at increasing the linkages between Georgia Tech and the partner schools. Graduate students are plugged into the events in their departments and in the broader university community, and are constantly reviewing these connections with an eye towards applicability to the high school community.

Graduate Fellow Participation

**Recruitment:** Despite initial skepticism by Georgia Tech faculty and administrators, the STEP program has become increasingly and highly popular among graduate students, particularly among the African American graduate students (see chart below). We attribute this to the strong involvement by black graduate students in community involvement and civic leadership activities, and to a powerful "word of mouth" promotion of the program within the minority community at the institute. The table below shows the ethnic and gender breakdown of the applicants and participants in the program for the first three years. Note the progressive increase in application number. (B=black, W=white, O=other, M=male, F=female.)

| **STEP Applicants** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | BM | BF | WM | WF | OM | OF | ?? | Total |
| Year One | 4 | 4 | 7 | 6 | 1 | 0 | 3 | 25 |
| Year Two | 10 | 4 | 9 | 2 | 4 | 4 | 11 | 44 |
| Year Three | 15 | 7 | 16 | 8 | 2 | 1 | 7 | 56 |
| **STEP Participants** | | | | | | | | |
| Year One | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 12 |
| Year Two | 4 | 4 | 4 | 0 | 0 | 0 | 0 | 12 |
| Year Three | 4 | 3 | 3 | 3 | 0 | 0 | 0 | 13 |

Between years one and three, the number of academic units represented by those applicants grew from five departments in two colleges to eleven departments in four colleges.

**Stage Three: Performance Outcomes**

STEP is, in essence, a grand experiment in partnership building. Can a highly technical, majority white, university, over an eight-year period, build meaningful partnerships with low-income and predominantly minority schools that will outlast the individual people and the external support, and that will yield quantifiable benefits to both sides?

Indications of Partnership Building

Sustainable partnerships must be built upon the efforts, concerns, and agendas of many people if they are to survive the departure of the original players. Bearing this in mind, our philosophy has been to encourage all STEP participants to expand the partnership network whenever possible, and to include academic departments, individual laboratories, campus offices, student organizations, business and industry partners, and professional societies on the university end, and as many teachers, school clubs, administrators, and students as possible on the K-12 end. Thus far, the most noteworthy aspects of this partnership infrastructure include:

- *Involvement by Large Numbers of Academic Units at Georgia Tech, including*:
  - 9 academic units in the College of Engineering
  - 4 academic units in the College of Sciences
  - The College of Computing
  - 2 academic units in the Ivan Allen College (for Liberal Arts and Social Science).
- *Active Participation by Minority Organizations*. Georgia Tech graduates more black engineers than any other institution in the country, and the Georgia Tech Black

Graduate Student Association, and the National Society of Black Engineers (NSBE) have been two of our strongest partners. The black graduate students have also involved the FOCUS program (which encourages minority participation in graduate school), the FACES program (Facilitating Academic Careers in Engineering and Science), EMERGE (Empowering Minority Engineers to Reach for Graduate Education), as well as 100 Black Men of Atlanta.

- *Involvement by NSF-funded Engineering and Science Research Centers***.**
- *Direct School-University Lab Partnerships* to foster research opportunities for teachers and high school students.
- *Involvement by Georgia Tech Offices and Organizations,* notably the Office of Undergrad-uate Admissions, the Women's Resource Center, and the Division of Professional Practice.
- *Involvement by Increasing Numbers of Teachers at Partner Schools.*
- *Involvement by High School Students in Georgia Tech-Sponsored Enrichment Activities***.**

<u>Graduate Student Outcomes</u>
All Fellows, at the end of their tenure, answer the journal question "What did you gain from being a STEP Fellow?" In answer, the graduate students wrote:

> *"An extreme sense of satisfaction at the contribution I made to my students' lives - no matter how small it was. It was also the first experience I've had that has made me seriously consider teaching as a career. I've even recommended it to several people."* Black female, $4^{th}$ year chemistry Ph.D. student

> *"The biggest thing that I gained was confidence. I have no problem standing in front of a class and lecturing."* White female, $2^{nd}$ year mechanical engineering Masters student

> *"The STEP program has changed my career objectives. I now want to, ultimately, use my Ph.D. to develop educational programs for high schools. I want to create partnerships between industry and high schools. Don't ask me how just yet; my thoughts are still evolving."* Black male, $5^{th}$ year physics Ph.D. student.

> *"I gained teaching and leadership experience. This experience has shown me how much I really enjoy teaching despite the shyness in my personality. The joy of seeing a student learn supersedes my insecurities. The burden I feel when I look at the problems that face our communities, compels me to share what I have learned from school, so that other can break cycles and achieve the best in life."* Black male, $5^{th}$ year Ph.D. electrical engineering student

Teachers also provided unsolicited comments about the partnership:

*"I need to tell you how much [the Fellow's] presence has meant to me. This has been my first year back in teaching after 23 years in industry and I had little idea of the level of the problems I would encounter. [The Fellow] has served as a confidant, a sounding board, another set of eyes, and a friend during this year. Further he has added a creative element by way of his ideas and suggestions. His contribution has been significant, not only to the program here but also to my sanity. I have had a sense of isolation because of the limited adult interaction available here and even though [the Fellow's] days here were limited, they were a breath of adult communication. His insight and willingness to delve into what we were seeing was useful. We have evolved many understandings of the problems here … and after the summer break I will be refreshed to start again."*
Written by a participating physics teacher

*"Hi. Last day of school here. Paperwork completed, reflecting for a moment. Wanted to commend to you on [the two Fellows'] work. They made this old teacher a believer. [One Fellow] brought a steadiness and steadfastness with her. Dedicated to labs, and slugging it out. [The other Fellow] brought fire and brimstone. He gave us 100-plus summer enrichment programs of which our kids are attending…, brought us to Calvin Mackie's talk, Lego Mindstorm, aided in interviewing Governor's Honors nominee, and big-brothered one of our students helping him gain admittance to NC A&T. I would term this year a success. See you soon!"*
Written by a participating chemistry teacher

Evaluation of the STEP program's effect on graduate students, using the assessment methodology described earlier, has revealed positive outcomes in:

- *Academic Content Mastery*: Graduate students teaching high school students must convey knowledge so that it is comprehensible to students who come from varying achievement levels and backgrounds. This requires that knowledge be thoroughly understood, condensed and distilled to improve its efficacy, a skill that has incomparable value for graduate students.
- *Teaching Interests*: Hands-on teaching experiences provide graduate Fellows with early opportunities to elucidate their interests in teaching as a profession - whether at a high school or college level. These teaching experiences require novel approaches to conveying knowledge to students, thereby encouraging creativity in a Fellow's own research objectives.
- *Academic Efficiency*: A graduate student's skill at time management strengthens through time spent with students - both inside and outside of the classroom. Most graduate Fellows willingly spend more time contributing to the program than is required. To accommodate this, graduate students conduct their research and schoolwork in a more efficient manner.
- *Professional Skills*: Working in a high school classroom helps Fellows improve their leadership, communication, and pedagogical skills and better-define their future professional and academic goals and objectives. It also provides them

with models of rewarding community service that are applicable to their future career, whether in education or industry.

- *Presentation and Publications*: During the first two years of the project STEP Fellows have participated in seven professional presentations, co-authored three conference papers, and attended three NSF workshops and seven professional meetings in their role as STEP Fellows.

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Teacher and School Outcomes

The teachers and school administrators have all been highly enthusiastic about their participation with the STEP program. Many have stated that STEP is unlike any other school enhancement program they have ever seen, and that among all of their school "partners", Georgia Tech is their best one and is the only one that actually provides meaningful classroom help. The benefits to the school, teacher, and students most often mentioned to the evaluation team have been:

- The injection of fresh energy into the classroom by the Fellows.
- The value to teachers of understanding the cutting-edge research that takes place at the university, and the value to high school students of being exposed to what the science and mathematics are used for at a higher level.
- The ability of the Fellows to provide novel and different ways of thinking about, and presenting, science and mathematics content, and to introduce the students to educational enrichment opportunities outside of their school.
- The access that the teachers and students gain to science materials, supplies, and equipment.
- The effectiveness with which the Fellows are able to transform the high school students' thinking about science from a view that science is a bunch of facts, to an understanding that science is a process, and a way of thinking.
- The additional time the Fellows provide for teachers to do other necessary school-related duties. Fellows also help teachers keep their "sanity" under difficult conditions, hopefully increasing the likelihood that the good teachers will stay at these challenging schools.
- The Fellows, particularly the African American Fellows, serve as invaluable mentors for the predominantly minority high school students. They are role models, tutors and cheerleaders, and always fight against the tendency of schools to lower the bar for minority students.
- Teachers gain access to summer research experiences at Georgia Tech, through the *Georgia Industrial Fellowships for Teachers* (GIFT) program, and can build personal connections with faculty and lab personnel. After Year 1, one STEP teacher participated in GIFT. During the summer after Year 2, 13 teachers from STEP schools participated in research internships at Georgia Tech as part of the Georgia Tech (GIFT) program, supported primarily by Research Experiences for Teachers NSF grant supplements.

Though many of these benefits are difficult to quantify, they are very tangible to the individual teachers. For the four overwhelmingly African American schools in the program, STEP is **<u>the</u>** reform initiative within the science department. It provides the teachers with a sense of being special, and a hope that together the school and Georgia

Tech can improve the situation they face and help them direct their students towards productive and gainful careers. In essence, the partnership provides the teachers and schools with an invaluable door to Georgia Tech, through which pass lab and classroom resources, science and engineering faculty speakers, high school students on laboratory tours, admissions officers bearing crucial advice, and undergraduate student volunteers. These are all types of resources that are traditionally unknown and unavailable at the African American schools but are commonplace at majority-Caucasian affluent schools (that each send dozens of students per year to Georgia Tech, and where many of the parents are connected to the university, either as an alumnus, a faculty member, or a member of the corporate elite). These "ripples" of resources extending from the partnership core are vital to the growth and vitality of the partnership; Fulton County's Tri-Cities High School STEP program, described below, gives a good example of this ripple effect in action. Tri-Cities and Georgia Tech had no existing relationship before STEP began in 2001.

Tri-Cities has now hosted seven graduate students and two undergraduates over a three-year period. The partnership ripples include: 1) High School students initiating a junior chapter of the National Society of Black Engineers (NSBE) (linked to the Georgia Tech NSBE chapter) which hosts academic activities and competitions, 2) Four science teachers participating in summer research internships in Georgia Tech Biology and Electrical Engineering laboratories, 3) Two teams of high school students conducting research projects at Georgia Tech, supported by the Siemens Foundation, 4) A College of Computing professor and Ph.D. graduate student piloting a new computer-based art program at the school, 5) A science teacher and faculty member from Aerospace Engineering collaborating on a grant to create a high school research-based Astronomy class, 6) Students from Tri-Cities American History classes exchanging visits with Georgia Tech students enrolled in a Social Policy course, 7) Tri-Cities students participating in internet conversations with students at Georgia Tech, and students in Russia and Sweden, 8) The minority recruitment team from Georgia visiting the school multiple times, 9) Teams of high school students participating in a Lego Mindstorm competition sponsored by Mechanical Engineering, 10) High school students visiting Georgia Tech to hear motivational speakers, 11) Students and teachers attending Biotechnology demonstrations, and 12) A relationship of trust and respect developing between people at Tri-Cities and Georgia Tech.

## The Evolution of the STEP Partnerships

As we are in the third year of STEP in several of our partner schools, we are now in a position to evaluate the initial success of our partnership building, and to look towards sustainability. The following evolutionary model of the development of a university-high school partnership based on graduate Fellows is now becoming apparent. It is also apparent that these stages cannot be rushed since the trust necessary for building true partnerships takes time to develop, and is based on actions over time, not on abstract plans.

### Year 1—Initial Steps

Goal—To develop an understanding by both university and school partners of the program's potential at that school.

- Graduate Fellows are introduced, and form personal bonds with school staff.
- School personnel develop an understanding of program possibilities, trust about university motives, and confidence of sustained university interest.
- The university partners analyze school's use of Fellows and the partnering capability of the school staff.
- The university partners assess whether the "need" is there—Does the partnership have the potential to have a major effect, or is it merely icing for a school which functions fairly well already?

**Year 2—Maturation and Expansion of the partnership**.
Goal—To establish the university as a "real" partner—i.e. one that can be trusted to continue for the long haul.

- The school transitions to a second graduate Fellow team. Teachers and school personnel learn that the partnership is not dependent on specific graduate students.
- The team of teachers and graduate students develop a broader concept about what the school's needs are, and how the university might interface with them.
- The network of teachers with "ownership" of the partnership expands.
- Multiple connections are developed between the high school and academic units and organizations at the university, including linking schools to particular research labs.
- Teachers are encouraged to come to the university as summer research interns.
- The team begins developing high school research teams to come to university labs.
- Undergraduate students or additional graduate students join the school teams where the partnership capacity allows it.

**Year 3—Beginning Institutionalization.**
Goal—To increase the number of "owners" of the partnership.

- Schools transition to a third graduate Fellow team and university-school connections expand.
- School system personnel become involved in the graduate Fellow summer training program.
- The partnership gains increased visibility and ownership among high-level administrators from both school system and university.
- Schools are encouraged to actively instigate additional school-university connections, thereby empowering teachers to ask for what they need.
- Staff seeks out and promotes partnerships and sponsors from the private sector.

All of the STEP partnerships are actively evolving and expanding. The goal of the next five years of STEP is to solidify the partnerships, creating enough linkages that the connections become sustainable without the infusion of NSF funds.

## Conclusion

Though there is a current national emphasis on developing partnerships between universities and K-12 schools, there has been little discussion on exactly what is meant by a "university-school" partnership, and very few theoretical frameworks exist for describing the best way of achieving sustainable and effective partnerships in education. The Partnership Conceptual Model described in this paper and drawn from the partnership literature from the field of Public Policy emphasizes the importance of pre-existing conditions (in terms of embeddedness and strategic needs) and the structure of the partnership (in terms of formation and operations) when predicting the success of the project outcomes. STEP is a partnership that began with congruent strategic needs and a high degree of embeddedness with the school system administration, but a low degree of embeddedness where it really counts, namely at the individual school level. Therefore high initial transaction costs, in the form of large amounts of time and effort, were required to develop the connections with the schools, and the necessary personal trust, that ultimately have led to a deeply embedded partnership and a higher chance for long-term successful outcomes.

With STEP the emphasis has been placed on the development of a healthy partnership and the final outcomes are allowed to evolve from the partnership. In our experience, this is not the most common orientation of educational partnerships; many are driven by particular prescribed activities, or based on curricular units developed by higher education. As illustration, one of the NSF reviewers for the STEP Up! GK-12 continuation grant stated:

> *"The process of creating the partnerships and working with the teachers is not new, original nor particularly creative. What is novel is the creating of the partnerships first and then letting what happens happen. This takes courage and faith in the participants. It also takes very secure college level faculty who are willing to treat their high school teachers as peers. This is obviously happening here with very imaginative results."*

Our experience suggests that the partnership itself is particularly important when trying to connect and effect change in entities with very different cultures, such as majority-white universities and majority-black schools. Only when the partnership is strong, and the different partners have trust in one another, can change take place. And only when there are clear mutual benefits and trust can a partnership outlast the external funding stream and sustain over time.

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